US Department of Interior
National Park Service
**Grand Canyon National Park**

# Monitoring Grand Canyon Springs for Assessment of Water Resources During Groundwater Withdraw and Climate Changes

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**2008 WRD Water Professionals Meeting**
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# Park Statistics

- Size = 1,180,862 acres (approx 1,850 $mi^2$)
- Elevation Range = 1,200’ to 8,000’
- Number of 7.5 minute quads that include park lands = 72
- Visitation (2001-2006) = Approx. 25,000,000

- Estimated number of seeps & springs = 200+
- Estimated miles of underground rivers & streams = 80+
- Number of side canyons = 300+

- 0.003% of the park is occupied by tributaries. Within that 36% of the total riparian flora are found.
- 500 times more species found in riparian areas than surrounding land

Deer Creek Falls

# Program Overview

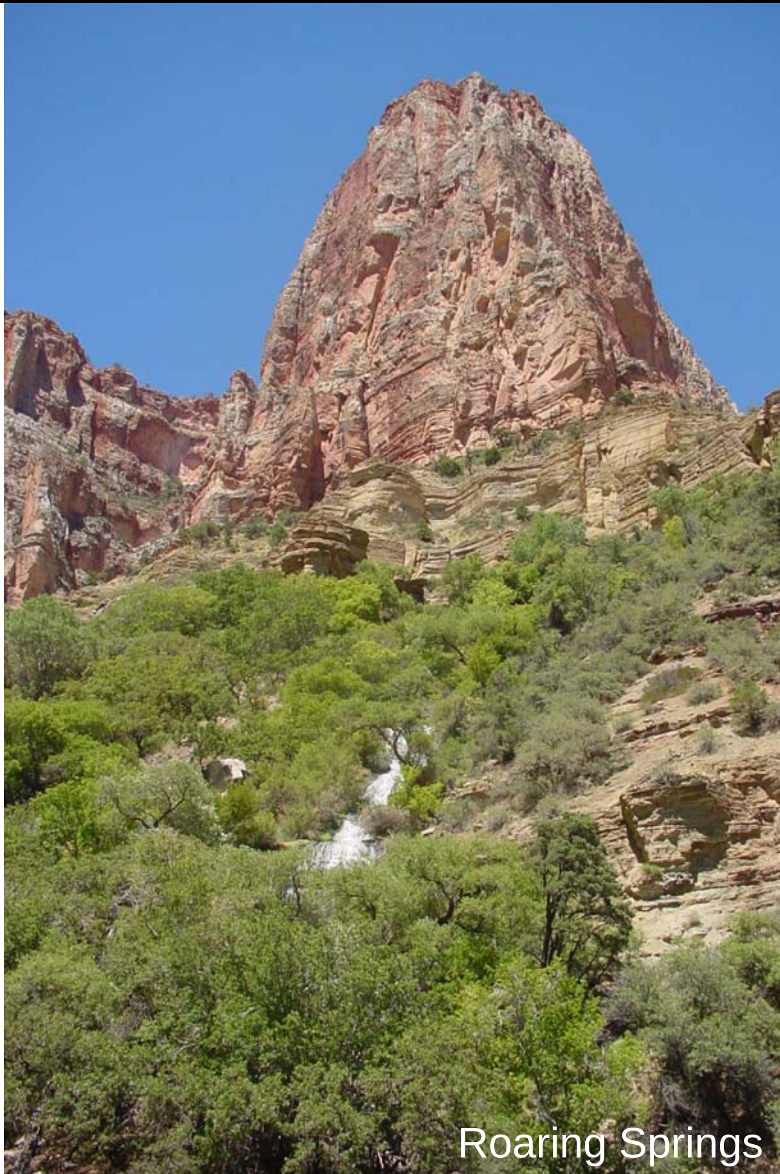
•Spring flow is a critical resource to Grand Canyon National Park

•Program documents trends in water quality, quantity, and spring / stream / watershed function

•Springs seen as a singular response to the hydrologic character of a much larger area

-Indication of the status of the supplying aquifer systems

•Planning and management for preservation and use of springs requires benchmark hydrologic dataset


Roaring Springs

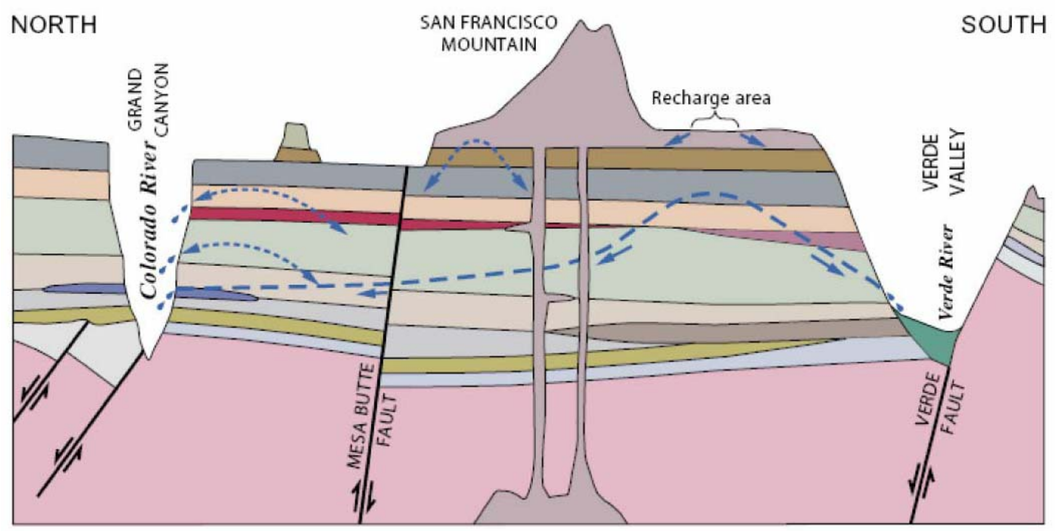
# Water Resources

•Infiltration of precipitation into the porous Kaibab limestone capping the Coconino Plateau is the major source of recharge to aquifers in the canyon.

•Only a small percentage of total precipitation makes it into the groundwater system.  Groundwater moves downward primarily along interconnected fracture zones.

•The majority of springs in GRCA issue from the regional carbonate “R” aquifer.

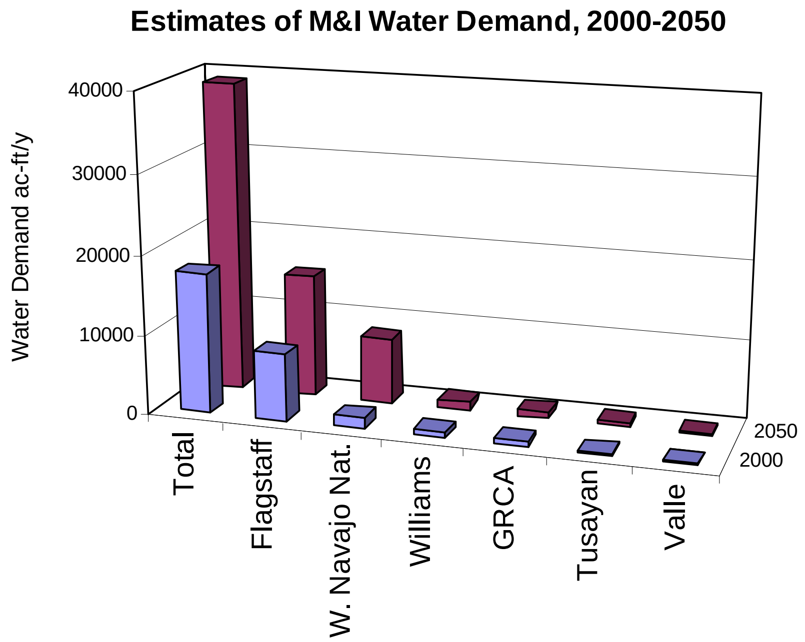
•Bright Angel Shale prevents most groundwater from penetrating below this zone.

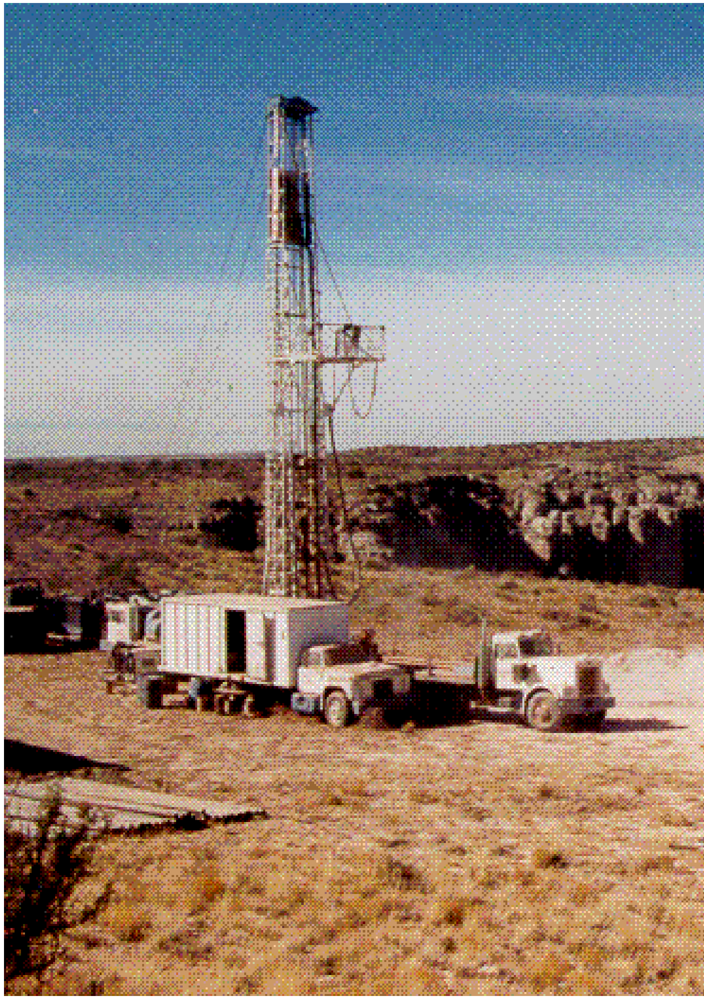



Generalized hydrogeologic cross section of the Coconino Plateau.  Modified from Flynn and Bills, 2002.

# Water Resources

- Critical for the survival of sensitive riparian areas.
- Groundwater developments on the Coconino Plateau threaten springs resources along the South Rim of Grand Canyon.
- Estimated doubling of water demand in the region between 2000 and 2050.

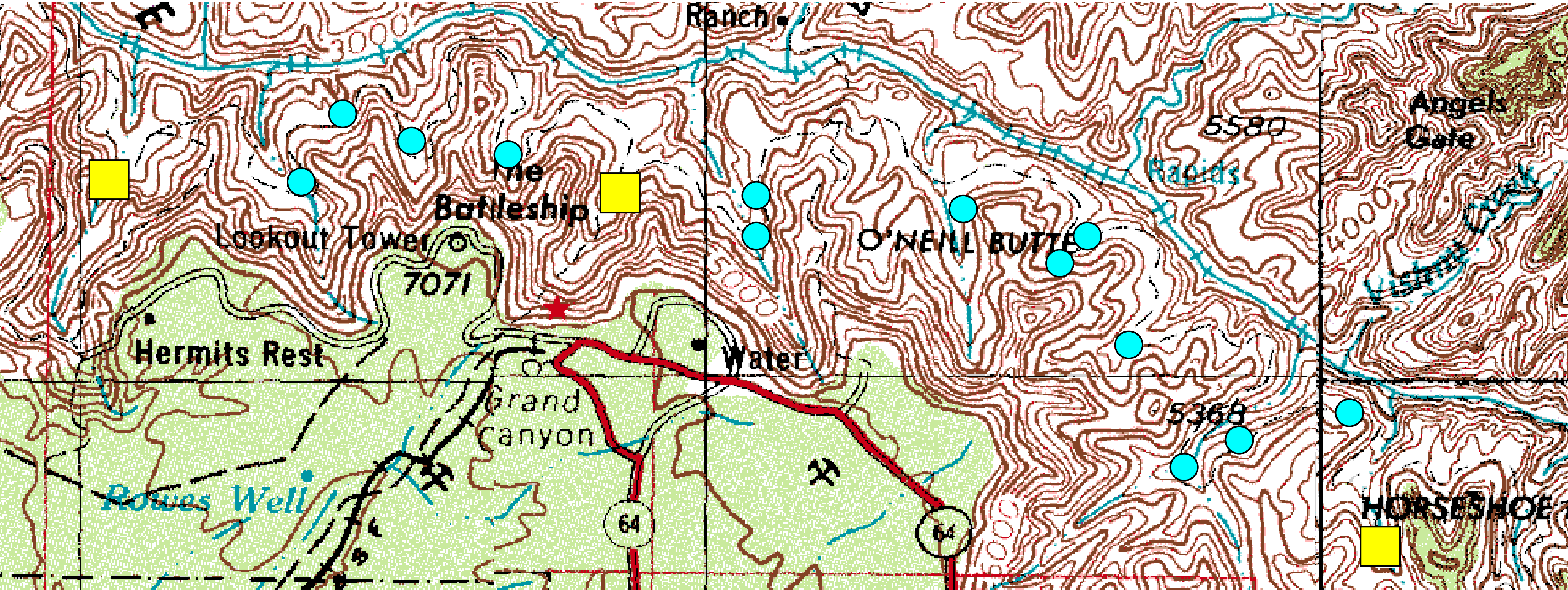


Sources: Morrison Institute for Public Policy, 2001 / Bureau of Reclamation, 2006

# Springs Monitoring

- Bimonthly visits to 16 sites along South Rim
- 3 Gaged, 13 Ungaged
- Along 40-mile stretch of Tonto Trail between Hermit and Grandview Trails
- Most springs issue from Redwall-Muav regional carbonate aquifer system
- Many associated with structural features (faults / fractures)



# Springs Monitoring

Site visits include:

- Assessment of site
    - Changes in vegetation (type, abundance)
    - Changes in stream morphology / flood evidence
    - Human activity

- Spring discharge measured using appropriate method
    - Volumetric container (low flow)
    - Flume (moderate flow)
    - Flow meter (large flow)

- Water quality parameters

- Water sampling
    - Dissolved constituents
    - Laboratory analysis



# Springs Monitoring – Water Quality Parameters

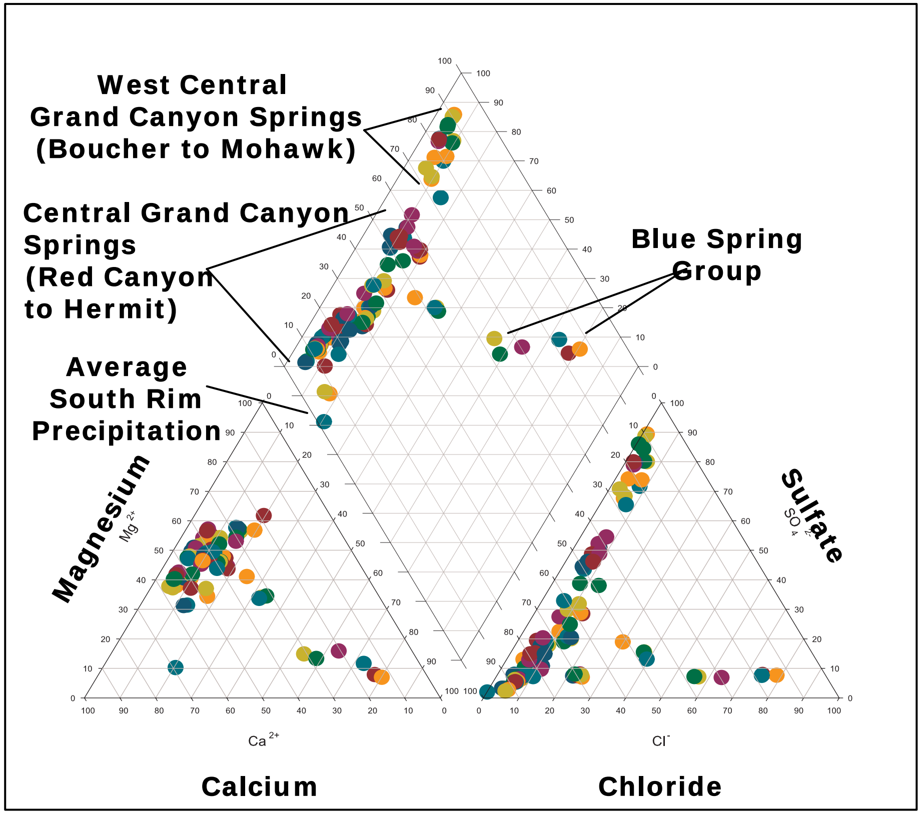
- Parameters measured:
  - pH, EC, TDS, DO, temperature

- Geochemical data collected / measured:
  - Alkalinity
  - Dissolved constituents
    - $NO_3$, $SO_4$, $PO_4$

- Laboratory analyses (periodically)
  - Isotopes (stable / radioactive)
  - Major ions
  - Nutrients
  - Trace elements

- Develop relationships / trends over time

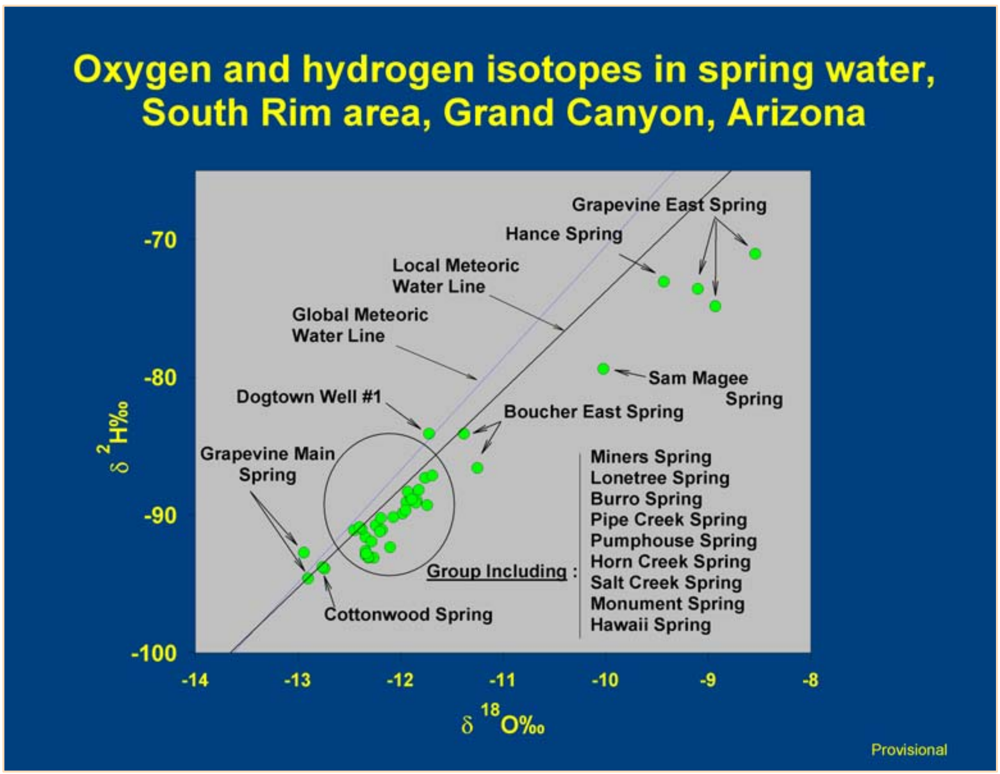
- Monitor MCLs



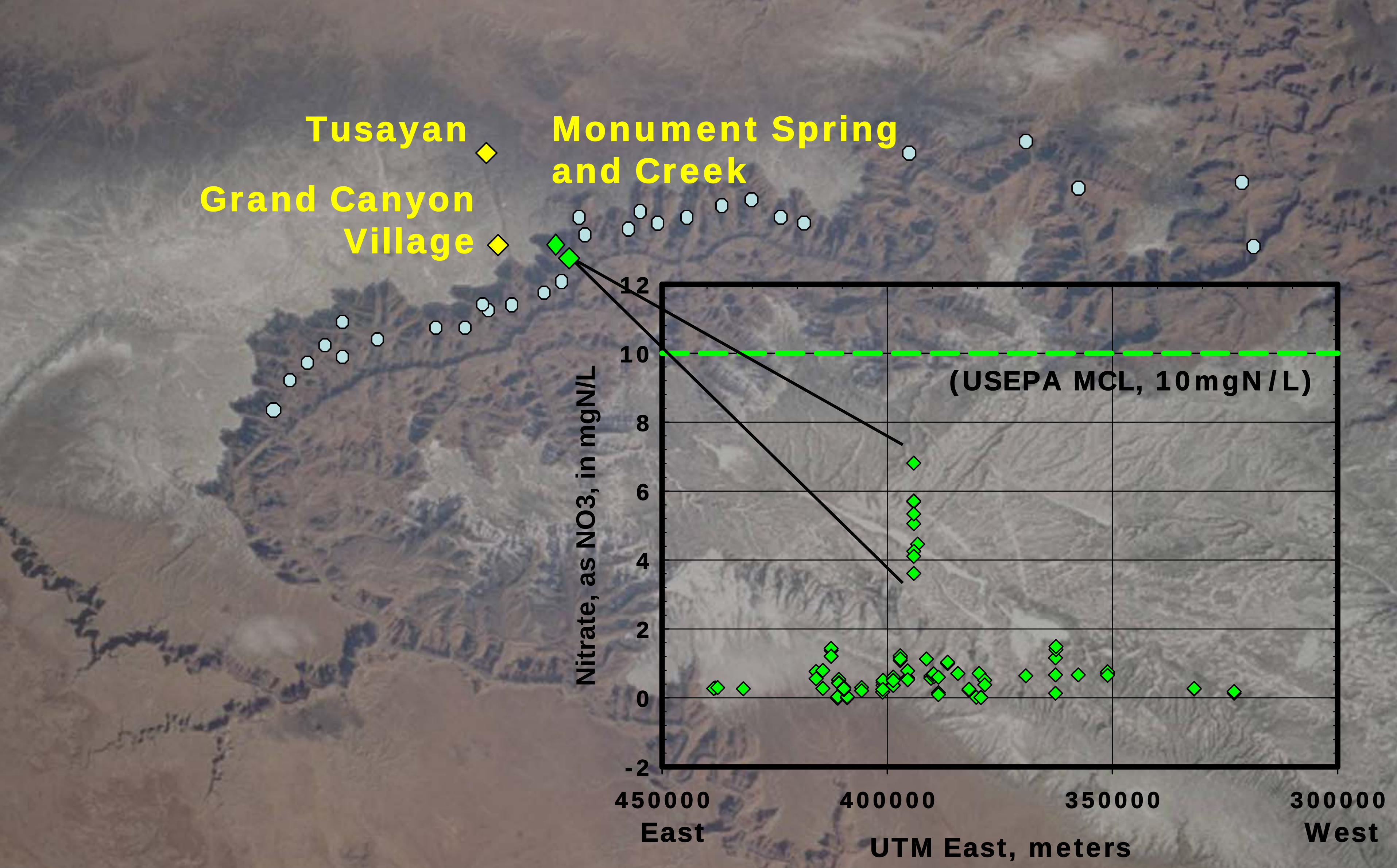

Piper diagram of relations of ion concentrations between South Rim springs.

# Springs Monitoring – Water Quality Parameters

- Changes over time
    - Effects of climate / groundwater mining?
- Recharge zones / seasons
- Groundwater flow paths




# Distribution of Nitrate at South Rim Grand Canyon Springs



# Gaging Stations

- Three gages operated along the South Rim:
    - Hermit Creek (1994-current)
    - Cottonwood Creek (1994-current)
    - Indian Gardens (1995-current)

- Each site has precipitation gage

- Gage type / design:
    - USGS-style stilling well / float / potentiometer
    - Solar-powered dataloggers
    - Record on 15, 30, or 60-minute intervals
    - Rating curves built from manual measurements of flow


Hermit Creek

# Trend Analysis

•The Seasonal Kendall (SK) test for trend selected to analyze gage data

- •Rank rather than numerically-based
- •Accounts for serial dependence
- •Accounts for missing data
- •Data collapsed to monthly and quarterly
- •Seasonal component compares similar periods
- •Assumes trend is monotonic

•Simple linear regression does not handle "seasonal" or missing data very well

•Very sensitive to outliers

# Trend Analysis

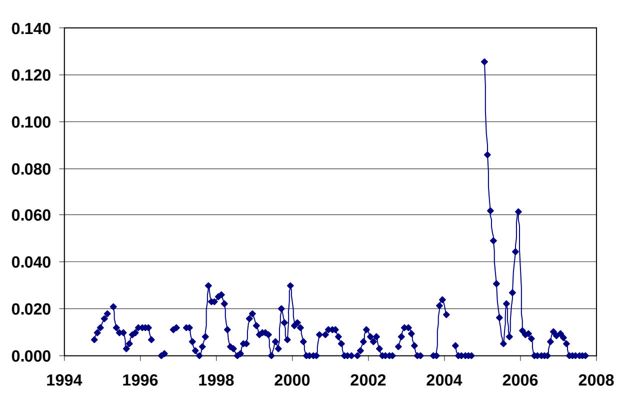
•Plots of discharge over time show seasonal fluctuations, variability, and storm peaks

•Cottonwood Creek has longer periods of no flow as time progresses

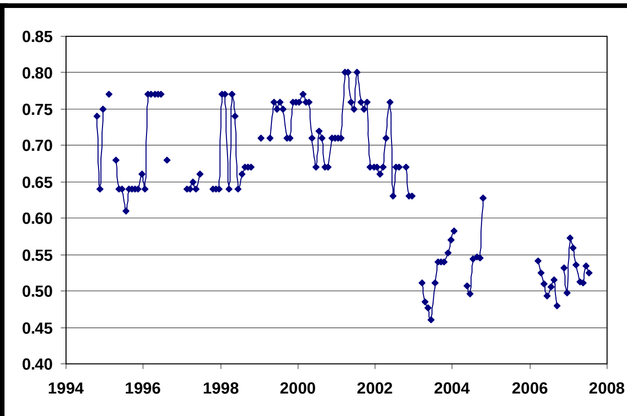
•Wet winter of 2004-2005 shows at Cottonwood and Indian Gardens.  Record missing from Hermit

•Seasonal effects strong at Cottonwood, weak at Indian Gardens

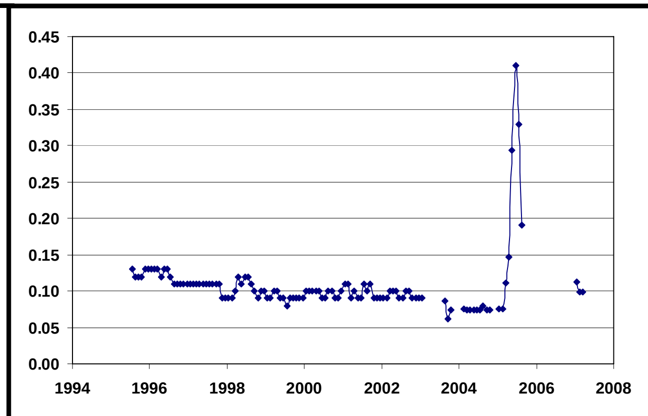
Cottonwood Creek




Hermit Creek




Indian Gardens



# Trend Analysis Results

•Output from test include s-value, p-value, and slope
•s-value (+1, -1, 0)

•Probability random dataset would yield s-value
•p-value below 0.05 (5%) is significant

•Slope shows change in discharge with time

•Test run on monthly and quarterly mean and median Q
•Monthly values adjusted for the effects of serial dependence

•Slopes of trend (if identified) compared against median Q

Vasey's Paradise

# Trend Analysis Results

- Results show statistically significant decreasing trends at Cottonwood Creek and Indian Gardens
- No discernable trend at Hermit Creek
- Slopes range from -0.00013 to -0.0033 cfs/yr
- Value small, but percent of median Q significant
- All sites have sizable periods of missing data attributed to mechanical / weather-related failures
- Data gaps to be minimized or eliminated by installation of modern gaging equipment

| Site | Type of Discharge | S= | p-value | trend ? | slope, cfs / yr | % median Q/yr (trend only) |
|---|---|---|---|---|---|---|
| **Cottonwood Creek 1994-2007** | Monthly Mean | -145 | 0.0953 | y | -0.00013 | 1.6 |
| | Monthly Median | -170 | 0.0884 | y | -0.00025 | 3.1 |
| | Quarterly Mean | -55 | 0.0366 | y | -0.00044 | 5.5 |
| | **Quarterly Median** | **-55** | **0.0328** | **y** | **-0.00042** | **5.2** |
| **Indian Gardens 1995-2005** | Monthly Mean | -167 | 0.0263 | y | -0.00330 | 3.3 |
| | Monthly Median | -169 | 0.0222 | y | -0.00333 | 3.3 |
| | Quarterly Mean | -49 | 0.017 | y | -0.00300 | 3 |
| | **Quarterly Median** | **-42** | **0.0337** | **y** | **-0.00333** | **3.3** |
| **Hermit Creek 1994-2007** | Monthly Mean | -115 | 0.1826 | n | -0.01227 | NA |
| | Monthly Median | -134 | 0.113 | n | -0.01275 | NA |
| | Quarterly Mean | -7 | 0.8044 | n | -0.00200 | NA |
| | **Quarterly Median** | **-14** | **0.5891** | **n** | **-0.00250** | NA |

# Trend Analysis Results

- Decreasing trends at 2 of the 3 gage sites indicate springs are being affected by a hydrologic variable, but it has not been identified
    - Climate change?
    - Pumping?
    - Combination or unknown variable?

- Discerning responsible variables:
    - Analysis of precipitation trends
    - Monitoring springs in areas unaffected by potential pumping effects

- Failure to recognize a trend at Hermit Creek can be potentially attributed to:
    - Actually no trend
    - Trend exists, but is not monotonic
    - Hydrologically different behavior
        - pathway, residence time, etc.
        - Isotopic support

Monkey Flower Spring

# New Gages

- Currently replacing 3 gage sites with new pressure transducer systems
  - Less invasive
  - More reliable
  - Use existing control & supports

- Economic design / installation allows for more sites
  - Install in safer locations
  - Extend S. Rim monitoring E & W
  - N. Rim gage(s) to compare precipitation vs. discharge relationship
  - Shinumo Creek HBC relocation

- Working with water supply department to instrument Roaring Springs as new permanent site

Hermit Creek gage after flash flood

# New Gages

•Designed to fully replace old gage systems minimizing modification

•Controls will be maintained

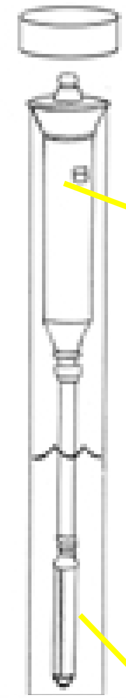
- •New records related to / combined with previous records

•PVC design provides secure housing for datalogger and sensor

•Perforations allow flow-through and minimizes sediment buildup

•Currently in prototype phase now

•Plan to have all gages replaced and running by summer 2008



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# Conclusions / Future Work

•Increased water demand / climate change push springs resources into spotlight

•Monitoring network developing a benchmark hydrologic dataset

•Cottonwood Creek and Indian Gardens show statistically significant decreases in discharge
•Hermit Creek shows no significant trend

•New gages being developed / installed to improve data quality and expand network

Colorado River at Nankoweap